Art. VIII.—*Geological Notes on the Country between Strahan and Lake St. Clair, Tasmania.*

(With Map.)

By Graham Officer, B.Sc., Lewis Balfour, B.A., and E. G. Hogg, M.A.

[Read 14th June, 1894.]

The following sketch is the outcome of observations collected during a trip made by the authors in January of this year from Strahan to Lake St. Clair along the overland track.

The first thing of interest, that does not seem to have been recorded as yet, is the occurrence about a mile from Strahan along the track of a deposit which bears a striking similarity to the glacial drift in Victoria. It consists of an unstratified or faintly stratified clay, of great hardness in places, and through which stones and boulders are irregularly scattered. One of these boulders was two feet in diameter, and several bore striæ. In places the clay has a peculiar pinkish-purple colour that is very characteristic of the glacial beds near Bacchus Marsh. As a similar deposit occurs on Mount Tyndall and also on Mount Sedgwick, not very far distant, it is not improbable that the two are identical. We did not observe a direct junction with the Silurian rocks which appear here and occur all the way to the great central plateau.

Mounts Lyell and Owen form part of the West Coast Range, and are at a distance of some thirty miles from Strahan by the track. These two mountains run approximately parallel to each other in an E. and W. direction, being separated by the wide, open Linda Valley. At their westerly extremity they are connected by a narrow saddle, which rises to a height of about 1500 feet above sea level; from this end arises the Linda Creek, which, after being joined by its tributaries, runs due east down the valley for about four miles, when it flows into the King River. Towards its lower end the valley narrows rapidly as the eastern spurs of Mounts Owen and Lyell approach each other.

The Linda Valley has attracted much attention owing to the gold found in its alluvial, and to the other valuable minerals occurring in the ridge bounding it on the west. As might have been expected, in the case of a valley lying between two high mountains composed mainly of the older formations in a highly disturbed region, the geological problems to which it gives rise are very complex.

The lowest rocks exposed consist of schists (principally hydromica), sandstones, quartzites, and conglomerates. These are all inclined at high angles, and have been assigned to Lower Silurian age. Capping and apparently forming the greater mass of Mounts Owen and Lyell is a great series of sandstones and conglomerates. The Linda Valley is to a great extent filled by more recent deposits. The so-called Silurian rocks occur at the upper end of the valley, and may be recognised again at the lower end on the Linda Creek. The ridge joining Mounts Owen and Lyell at the west extremity of the valley is almost, if not entirely, composed of schist. Owing to accumulations of *débris* and the occurrence of thick scrub, and consequent difficulty of observation, it is very hard to determine with anything like precision the geological relationships of the rocks in this country. While certain Lower Silurian fossils have been obtained from rocks in the vicinity, yet, until a careful survey is made, it will be very difficult indeed to assign any given outcrop to a certain age. There are at least two sets of the older rocks with an unconformity between, and it seems quite possible that there may be a third. Thus we should not be surprised if the schists forming the ridge at the head of the Linda Valley turned out to be Cambrian or even Archæan.

Pyrites occurs abundantly through these ancient rocks, and micaceous and specular iron is plentiful ; veins of the latter can be seen traversing pink conglomerate, in which the included pebbles are apparently all of quartz and quartzite.

One of the principal features of the western end of the Linda Valley is the now celebrated "Iron-Blow," a mass of hæmatite, and the closely-associated lode (so-called) of pyrites, which is now being worked by the Mount Lyell Company. This mass is apparently interbedded with the country rock, and is inclined at about 63°. The hanging wall is schist, and the footwall conglomerate.

The lode which the Mount Lyell Company are working consists essentially of pyrites. According to Dr. Peters, whose report on the mine was published last year, the great bulk of the ore mass consists of iron and copper pyrites, with a little heavy spar (barium sulphate), and silica, and traces of antimony, arsenic, lead and zinc. This ore also contains about 3 oz. of silver and $2\frac{1}{2}$ dwt. of gold to the ton. Besides this main body of ore, pockets of argentiferous copper pyrites and silver-copper glance occur. This class of ore has proved enormously rich, yielding several thousand ounces of silver to the ton, besides a large percentage of copper.

Several theories have been put forth to account for the formation of the ore, but the most satisfactory is that proposed by Dr. Peters and Mr. Montgomery. According to these gentlemen, the mass of pyrites is an ore-bed contemporaneous with the enclosing country rock, having been probably deposited in a swamp or lagoon of the period. The ore-bed has a thickness of 300 ft. at the surface, this thickness representing, on the above theory, the original depth of the deposit, which may therefore be pretty confidently expected to be of very large extent.

Resting unconformably on the older schistose rocks, with their accompanying sandstones and conglomerates, are massive beds of conglomerate interstratified with sandstones, which are very characteristic of the West Coast Range as a whole. These beds may be traced from the level of the Linda Valley to the summits of both Owen and Lyell. They have in general a south-westerly dip at an inclination of about 40° to 45°; but at the top of Mount Lyell, where they constitute the plateau on which the trigonometrical station was erected, they are dipping to the N.W. at an angle of 15°. They are much jointed, and show a tendency to foliated structure. The included stones, which are almost invariably quartz and quartzites, vary in size from small pebbles to boulders of at least two feet in diameter, thus giving the rock a very striking appearance. The beds are pierced by quartz-veins, which traverse both matrix and included pebble, and the jointing planes, in dividing the rock, also cut right through the quartz pebbles. The foliated structure, which causes the quartz to flake off in thin sections, would appear to show the intense compression to which the beds have been subjected. The matrix of the conglomerate is a hard, silicious sandstone. The interstratified sandstones, which occur in beds of considerable thickness, vary greatly in character, some being fine, others coarse, and others highly micaceous. A bed of the micaceous sandstone, overlaid by a fine conglomerate, forms the summit of Mount Lyell. From the conglomerate and sandstones lying at the western end of Mount Lyell gold has been obtained in more or less payable quantities. The rocks have in general an appearance of great antiquity, and extending as they do over a large tract of country, their origin, geological age, and the position of the quartzitic highlands of which they are the *débris* are questions of great interest. So far as our examination of these beds went, they were unfossiliferous; but certain sandstone boulders containing fossils found on West Mount Lyell, and also on the button-grass plains lying east of the King River, may yet be traced to them. Mr. Moore is of opinion that they should be classified as Devonian. Mr. Montgomery, Government Geologist, in his recent paper on "Glacial Action in Tasmania," states that the Owen conglomerates are conformably interbedded with the quartzites and schists of this district. If he refers to the conglomerates forming the mass of Mount Owen, as we presume he does, our observations lead us to believe that this is erroneous, and that, as we have already stated, there are two sets of conglomerates here—one intercalated with the schists and sandstones, the other—the massive Owen conglomerates—lying unconformably over them.

Among the beds of later origin in the valley is a soft black clay, called by the miners "pug." It attains a considerable depth in places, and rests unconformably on all the older rocks. It is in places stratified, and is said to contain intercalated beds of lignite. It is reported that shells have been found in it, though we were unable to detect any. It contains numerous particles of free pyrites, and would appear, without doubt, to have been formed by the disintegration of the adjacent schistose rocks containing pyrites. Its distribution is confined to the western end of the valley. There is a good outcrop of it just beneath the Iron Blow, and it may be also found at Karlson's Face and at a considerable elevation on the saddle on the Copper Creek. It is probably of lacustrine origin.

Overlying the "pug" is a series of clay, sand, and gravel beds. Two typical sections may be seen on the track to the Queen River, within a short distance from the Iron Blow. The first of these consists of soft irregularly-stratified clay, with bands of grit and larger stones here and there. These rest upon schist, which is much broken and decomposed. It is covered by angular hill-wash. The second, a little further on, shows an unstratified clay containing numerous rounded, angular and sub-angular stones irregularly scattered through the matrix. The stones range from small pebbles up to boulders a foot in diameter. Irregular bands of stratified material, stained with iron, occur here and there. The included stones consist of quartz, quartzites, and hard sandstones, evidently obtained from the adjoining hills. Some of the stones are well striated. On the track between the boarding-house and the Iron Blow occur patches of a dark, tenacious clay, from which well-marked striated stones were procured.

Mr. T. B. Moore, in a recent paper recording the discovery of scored stones from this locality, states that the Linda Valley is covered with a layer of morainal matter. He is also of opinion that "the deep ground hydraulically sluiced" for gold in the upper part of the Linda Valley "is nothing but a huge mass of morainal matter."

Although striated stones undoubtedly occur in the Linda Valley, we must be careful not to ascribe too much to the action of ice, for it must be borne in mind that landslips and other gravitational results may produce, to a greater or less extent, many of the effects noticed in a glaciated area. Further research may bring to light other evidence of glacial action in the shape of *roches moutonnées*, erratics, &c.; and in the absence of such evidence we hestitate in coming to any definite conclusion as to the origin of the striations observed.

The head of the valley, which we should have expected to be somewhat bare and denuded of surface material, had it been occupied by a glacier, within Pleistocene times at least, is filled to a great extent by the pug, clays, gravels, &c., already referred to, besides a great accumulation of angular *débris*, which has gravitated from the adjoining heights. We are inclined to think that much of the morainal matter referred to by Mr. Moore is simply this gravitated *débris.* Any appearance of *roches moutonnées* is quite absent ; on the contrary, whenever any of the bed-rocks appear, they are invariably rough and rugged. The slopes of both Mounts Owen and Lyell are studded with great masses of conglomerate, which have moved down from above, and here and there huge columns of rock, often with smaller blocks perched on their summits, may be seen, and which have evidently weathered into their present state *in situ.*

Lake Beatrice lies some ten miles from the King River Crossing, between Mount Sedgwick and Eldon Peak. It is in the same line of drainage as Lakes Dora, Rolleston, and Spicer, which lie to the north. A stream flows out of the lower end of the lake, which, after a course of two or three miles, joins the King River. This stream is remarkable for the immense size of the boulders in its bed. Not only in the bed of the stream, but on either side, spread over the low-lying ground, do these boulders occur in great profusion. The accumulations show a decided tendency to form ridges. The boulders consist principally of a very hard grit or fine conglomerate, and many of them must be tons in weight. The country here is so densely covered by scrub (beech, sassafras, "horizontal," and bauera) that we found it almost impossible to get any observations of the bed-rock.

The ridge-like form of the boulder accumulations at once suggests a morainic origin. As Messrs. Dunn and Moore showed last year, well-marked evidences of glaciation occur about Lake Dora and the other lakes no great distance away; and Lake Beatrice, as already remarked, is in the same line of drainage; so it would not be surprising if these boulder accumulations really owe their origin to glacial causes. The action of water alone does not seem sufficient to account for their transport, although it is true immense floods must have poured down this valley when the upper parts were occupied by glaciers and almost perpetual snow during the Pleistocene period.

Mr. T. B. Moore states that the King River Valley is covered with morainic matter. Numerous boulders of white sandstone, up to two feet in diameter, many containing masses of brachiopod fossils, are scattered over the valley, being generally concealed by the peaty soil and thick button-grass. Some of this material may have been originally morainic; but, in the absence of further evidence, it seems to us most probable that it has been distributed to its present position by the King River when flowing at a higher level. On the overland track a cutting occurs, about one-third of a mile from the crossing, which shows a "wash" of water-worn pebbles and boulders that is evidently of fluviatile origin, and which is about fifty or sixty feet above the present level of the stream.

If we are to believe that these boulders have been transported to their present position by the direct action of ice, we will have to admit a much wider glaciation in Tasmania than is generally believed to have taken place, the height of the King River Valley at this place being only 600 or 700 feet above the sea. We may add that other evidence of glaciation in the form of *roches moutonnées* and ground moraines seemed to be quite absent. We noted a large mass of greenstone lying close to the track about a mile from the crossing, and resting on Silurian, which is much decomposed and broken up on the surface. But it would be unwise to infer much from this one instance. There may be a dyke in the vicinity.

From the King River to the Victoria Pass the rocks are of an ordinary Silurian type—slates, shales, and sandstones. Fossils are abundant in places. At a cutting on the track near the King River crinoids were abundant, and trilobites and other forms were common, but we saw no graptolites. Our specimens have unfortunately gone astray.

From Victoria Pass the character of the rocks changes to white quartzites and quartz and talcose schists, while the hills are much barer of vegetation than those further west, a fact probably due to the nature of the rocks, which are, of course, nearly pure silica. At the Collingwood River micaceous sandstones occur, and then from the Franklin River, the white quartzites and schists extend to Mount Arrowsmith. Mount Arrowsmith is just at the edge of the great central plateau of Tasmania, which varies from 2000 to 4000 feet above the sea. Leaving Mount Arrowsmith, the Silurian rocks are also left behind, and one sees instead the massive greenstone crests of Mounts Gell, King William, Rufus, Hugel, and other more or less prominent heights.

At a lower level than the majestic greenstone columns at the summit of Mount King William I. are the almost horizontal beds of the Carboniferous sandstones. The characteristic fossils are very abundant (spirifers, fenestellidæ, &c.). Immediately below the columns, a section clearly shows that this sandstone has been subjected to a severe baking. The rock has been hardened and browned, and much resembles in consistency a well-made brick. In the short time at our disposal we were unable exhaustively to search for fossils ; but, in a few instances, evidences of their former existence in the deposit was established by the presence of a few casts. Instead of showing clearly, as in the section a few hundred yards away, these remnants, too, bore signs of considerable baking, which seems to be additional evidence on the comparative ages of the greenstone and Carboniferous sandstones.

Some discussion has been going on, and differences of opinion have been expressed, on this point. Gould, Strzelecki, and Tenison-Woods considered that the greenstone was post-Carboniferous. Jukes suggested the possibility of its being pre-Carboniferous. Mr. R. M. Johnston maintained the latter view in his "Geology of Tasmania." Professor David, in his presidential address before the A.A.A.S. at Hobart, thought that the greenstone was decidedly of later age than the Carboniferous and Mesozoic rocks. Mr. Graham Officer, in a paper read before the Royal Society of Tasmania last year, produced evidence that the greenstone was post-Carboniferous. Mr. Montgomery's observations also confirm this view. It is only fair to say that Mr. Johnston has modified his views, and now considers, with most other observers, that the greenstone is post-Carboniferous, although he has not yet published this opinion.

The difficulty in deciding this question has always been to obtain the point of contact ; a difficulty caused principally by the disintegration and subsequent falling of the greenstone columns, which generally obscure the line of junction. In this section, however, although the actual point of contact is not exposed, the sandstone is observed at a distance of only a few yards from the vertical greenstone columns, and as the former bears unmistakable evidence of having been subjected to a considerable amount of heat, the inference is that the greenstone has been erupted through the sandstone. The later age of the former may now be considered an ascertained fact.

Lake George, which lies at the foot of Mount King William, has been put down as probably of glacial origin. If this be a fact, further evidence must be adduced to support it. We traversed the steep slopes leading down from the mountain without observing any evidences of former ice action. The horizontally bedded sandstone forms a series of terraces across the gorge leading down to the lake, a form one would hardly expect to see if the rocks had been recently ice-worn. However, there is a large bank or low hill across the lower end of the lake, the appearance of which in the distance certainly suggests a moraine. We were, however, unable to reach it, as the day was far spent.

About eight miles south-west of the southern extremity of Lake St. Clair lies Lake Dixon, a small lake a few acres in extent. The rocks in the immediate neighbourhood present points of considerable geological interest.

The lake is picturesquely situated in a valley about 2000 feet above sea-level, while the eminences within a few miles rise to a height of another 2000 feet.

The Franklin River, here near its source, having flowed through Lake Undine a few miles north, enters Lake Dixon at its northern extremity, emerging again at the southern end.

The neighbourhood of Lake Dixon forms the junction of the east and west drainage areas of Tasmania. The Franklin runs with a general south-westerly direction, afterwards joining the Gordon, which ultimately flows into Macquarie Harbour on the west coast ; while Lake George, at the foot of King William I., about seven or eight miles south of Lake Dixon, and also the Cuvier, a few miles north, drain into the Derwent.

Especially on the western and northern slopes of Lake Dixon are seen numerous outcrops of the Silurian, or possibly older, rocks. They are composed principally of quartzites, quartz-schists, and talcose schists, and are in many places exceedingly hard.

They are all highly inclined, with a general north and south strike. They present wavy, flowing outlines, the exposed smoothed and well-polished surfaces glittering in the sunlight. Individual striæ it is difficult to find, this being probably due to the nature of the rock, but the general form and surface is typical of *roches moutonnées*—so typical, in fact, as to render a detailed description unnecessary.

In some places recent soil and grass have covered these polished surfaces, but enough is exposed to show that there exists a considerable area of *roches moutonnées.* In other spots, where the surface is quite bare, erratics of various sizes rest immediately on the polished rock.

Of morainic matter there is abundance. The surface of the country round the lower end of the lake, extending for about a mile from the lake, is strewn with rocks of all sizes and shapes and in all positions. Many are large, being some tons in weight, while others are small or of only moderate size. They are composed almost exclusively of greenstone, and it may be mentioned that it is at times difficult, if not impossible, to determine the line of demarcation between the moraines and the shattered columns of greenstone which have gravitated down the valley. Quartzites also occur in the moraine.

Mr. Johnston, in a paper read before the Royal Society of Tasmania last year, remarks that "the romantic . . . valley of Lake Dixon is, *par excellence*, the ideal of a perfect glacier valley. No one, however ignorant of glacial action, could in this neighbourhood gaze upon those beautiful, scooped, or rather abraded, lakes or tarns, . . . the snow-white, polished, billowy, cascade-like *roches moutonnées*, composed of quartzites, on the upper margin of Lake Dixon, together with the tumbled moraines and large erratic on the lower banks—at a level of about 2000 feet—without being impressed with the idea that its singularly characteristic features must have been produced by the slow rasping flow of an ancient river of ice."

In addition to the smoothed rocks, we discovered, clinging to to these surfaces, and principally in the hollows, part of the former ground moraine. This consisted of an intensely hard matrix of clay, in which were embedded and cemented together pebbles and stones of various kinds and sizes, composed of schists, slates, quartzites, greenstone, and other varieties. No attempt at arrangement is discernable, and one distinguishing feature is the occurrence on many of the included stones of scores and striæ. These striations are numerous and well-marked, which, taken in conjunction with the character and position of the matrix, mark the deposit as a true till or ground moraine.

Lake Dixon, to all appearance, is very shallow. Its edges are not deep, though some of the slopes above are decidedly steep. Reeds grow in the lake for some distance from its northern extremity. It is quite probable that Lake Dixon is a morainic lake.

As to the age of this ice action, it is difficult to say more than that everything tends to show that it has been the work of recent glaciers. The finding of erratics still resting on the polished surfaces is suggestive, while the valley seems to have altered but little since the time when the river of ice slowly made its way downwards.

At first sight it seems strange that we have such direct evidence of glaciation in this valley of the Lakes Undine and Dixon, while the evidence in some of the surrounding valleys is negative. It is of importance, however, to remember that elevation is but one condition essential for the former glaciation in this region. Important elements to be considered are the contour, size, and length of the valley. This valley seems to be admirably adapted, not only for being a gathering-ground of snow, but also for the conversion of this snow into a glacier. Surrounded as it is by mountains rising to a height of 2000 feet above its level—itself 2000 feet above the sea—snow would inevitably collect to some considerable extent, while the slope of the valley would cause sufficient movement in the glacier to enable it to carve and polish and scoop the hard rocks. Added to this, the glacier would be supplemented by tributaries descending from the minor valleys to right and left. At present the snow in winter must be considerable. The last of the previous winter's snow had not melted on Olympus by the end of January, so it is not necessary to assume a very extensive fall of temperature to account for perpetual snow in these regions.

The geology of Lake St. Clair has already been described by Mr. Officer (Trans. Roy. Soc. Tas., 1893). The main features are similar to those about Mount King William, the mountains—*e.g.*, Olympus, Byron, Cuvier, Ida, etc.—consisting of a base of sandstone (Permo-Carboniferous), capped by greenstone. The possibility of its being a glacial lake is worth considering. There is a great accumulation of greenstone *débris* at its southern end, but it is difficult to say if it is *in situ* or not. The ridge-like form much of this *débris* takes is at least suggestive of moraines.

BIBLIOGRAPHY.

Rev. J. E. T. Woods—"A Physical Description of the Island of Tasmania." (Proc. Roy. Soc. Vic., 1882.)

F. Stephens, M.A., F.G.S.—"Notes on Boring Operations in Search of Coal in Tasmania." (Proc. Roy. Soc. Tas., 1885.)

R. M. Johnston, F.L.S.—"Notes on Geology of King River." (Proc. Roy. Soc. Tas., 1886.)

R. M. Johnston, F.L.S.—"The Geology of Tasmania, 1888."

G. Thureau, F.G.S.—"The Iron Blow at the Linda Goldfield." (Proc. Roy. Soc. Tas., 1889.)

R. M. Johnston, F.L.S.—"The Iron Blow at the Linda Goldfield." (Proc. Roy. Soc. Tas., 1889.)

S. H. Wintle, F.L.S.—"The Physical Conditions under which the Chief Coal Measures of Tasmania and Victoria were formed." (A.A.A.S., 1890.)

A. Montgomery, M.A.—"Notes on Some Geological Observations on the West Coast." (Proc. Roy. Soc. Tas., 1890.)

F. D. Power, F.G.S.—"Notes on the Mount Lyell District, Tasmania." (Proc. Roy. Soc. Tas., 1891).

Professor David, F.G.S.—President's Address, Section C. (A.A.A.S., 1892).

A. Montgomery, M.A.—"Glacial Action in Tasmania." (Proc. Roy. Soc. Tas., 1893).

G. Officer, B.Sc.—"The Geology of the Lake St. Clair District, Tasmania." (Proc. Roy. Soc. Tas., 1893).

T. B. Moore, F.L.S.—"Discovery of Glaciation in the vicinity of Mount Tyndall in Tasmania." (Proc. Roy. Soc. Tas., 1893).

E. D. Peters, Jun.—"Report on the Property of the Mount Lyell Mining and Railway Company." 1893.

R. M. Johnston, F.L.S.—"The Glacier Epoch of Australasia." (Proc. Roy. Soc. Tas., 1893).

Report of the Secretary of Mines, Tasmania, for 1892-3.

E. J. Dunn, F.G.S.—"Glaciation of Western Highlands, Tasmania. (Proc. Roy. Soc. Vic., 1894.